Access Pricing and Infrastructure Investment

by

Joshua S. Gans*

First Draft: 24th August, 2004
This Version: 25th October, 2004

This paper reviews and synthesises the recent literature on the impact of access price regulation on investment incentives. In so doing, it emphasises key themes that such regulation can improve investment outcomes, it can do so while encouraging competition and that pricing outcomes relate to both fully distributed cost methodologies and Ramsey pricing. *Journal of Economic Literature Classification* Numbers: L40, L50.

Keywords. access pricing, essential facilities, infrastructure investment, access holidays, regulatory commitment.

* Melbourne Business School, University of Melbourne, 200 Leicester Street, Carlton VIC 3053, Australia. All correspondence to J.Gans@unimelb.edu.au. The latest version of this paper will be available at www.mbs.edu/jgans.

1. Introduction

Much of the literature on the regulation of access to natural monopoly infrastructure concerns the setting of simple linear prices. In this regard, issues involve the vertically integrated nature of some firms, multi-product issues, incentives for cost reduction and, in some cases, the recovery of fixed investment costs.[1] Of course, in regulatory circles the main issue that arises concerns the impact of access regulation on investment incentives. Put simply, it is argued that, in many network and infrastructure industries, productivity comes from new investment and access regulation, to the extent that it reduces the returns to such investment, harms overall efficiency.

Some recent papers have taken this notion very serious. Noting that these issues are a staple on the literature on innovation incentives, in a series of papers, Gans and Williams (1999), Gans (2001) and Gans and King (2004a) have considered the impact of access regulation on the timing of infrastructure investment.[2] They find that access pricing regulation can actually improve investment timing outcomes and that it is not simply the case that such regulation has a dampening effect. Given this, this paper considers that set of models and nests them within a common treatment of investment incentives. In so doing, it generalises some of their results; especially with regard to the treatment of asymmetries between firms. As such, the hope is that some of the insights gained from that literature can be made more accessible to regulators and practitioners interested in access regulation.

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[1] See Armstrong, Cowan and Vickers (1994) and Laffont and Tirole (1999) for excellent treatments.

[2] Valletti and Cambini (2004) also look at investment in an access context. They consider how interconnection regulation in telecommunications impacts upon investments in quality by both networks. In contrast, this paper is concerned with one-way access pricing situations with a single bottleneck provider.

The paper proceeds as follows. First, in Section 2, I introduce a simple model of investment timing based on the innovation model of Katz and Shapiro (1987). In Section 3, I then consider what happens when there is no access regulation as a means of providing a benchmark from which to assess access regulation. Section 4 then considers optimal access pricing. It does so by modeling that pricing as a two part tariff. The principle insight is that the fixed charge in that tariff can be used to control investment timing. Moreover, the ultimate form of the charges paid resembles a fully distributed cost methodology. Section 5 then considers the role of usage charges in determining investment incentives and also whether access holidays – that is, fixed periods for which an investor is free of any regulation – can improve investment outcomes. A final section concludes and offers suggestions for future research.

2. Model of Investment Timing

In many situations, policy-makers consider infrastructure investment as a simple ‘invest or not’ decision. In reality, however, the relevant margin is not if an investment will take place but when. The concern of infrastructure providers is that unfavourable or uncertain regulation may unduly delay investment. This is, of course, also a concern for policy-makers. However, they must consider not only the timing of investment by providers but also the timing of investment by access seekers – who deliver further benefits to consumers.

Given this, here I present a model of investment timing. To keep things simple, there are only two firms who may have use of a particular infrastructure asset. I distinguish between two cases. The first is where both firms may conceivably become the provider; in this case, we have the potential for infrastructure investment competition. The second is where only one firm is a potential provider; i.e., an infrastructure investment monopoly. This may arise because the other firm is wealth constraint, capital markets are imperfect or there are other constraints on investment by them.

In any case, our focus is on the timing of investment by the first firm to invest. As will be demonstrated, while it might be possible for the second firm to duplicate the facility, this will not occur in equilibrium. Thus, I term the first investor as the provider, *P*, and the other firm as the seeker, *S*.

Investment costs

The model here is based on the dynamic R&D model of Katz and Shapiro (1987); who examine a model with discrete time periods of length Δ but explore continuous time solutions as Δ approaches 0. In each period, firms make a decision as to invest or wait. It is assumed that there is no delay between a decision to invest and the appearance of the infrastructure. A firm investing at date *T*, incurs a current cost of investment of $F(T)e^{rT}$, where the discount rate $\delta = e^{-r\Delta}$ and $F(T)$ is the present value, viewed from time 0 of investment expenses.

It is assumed that these costs of infrastructure investment decline due to technical progress. In this case, $d(F(T)e^{rT})/dT < 0$ and $d^2(F(T)e^{rT})/dT^2 > 0$. Let F be the limit of current investment costs as T approaches infinity and F_0 be the cost of investment at time 0. A functional form that satisfies these properties is: $F(T) = F_0 e^{-\lambda T}$ (where $\lambda > r$) with investment costs declining exponentially. It is also assumed that the asset does not deteriorate over time or with usage (avoiding the need to consider re-investment and maintenance incentives). Finally, as the focus is on the recovery of fixed investment costs, it is assumed that use of the infrastructure involves a zero marginal cost.

Investment benefits

The following notation describes firm flow profits from investment for firm $i \in \{1, 2\}$

- π_i : duopoly profits for firm *i* if no investment takes place;
- Π_i^m : monopoly profits for firm *i* if it has exclusive access to infrastructure;[3]
- 0: profits if the rival firm has exclusive access;
- $\Pi_i^c(a)$: duopoly profits to firm *i* net of fixed access charges if both firms have access to infrastructure and the access seeker pays a unit price equal to *a*.

The following natural relationship is assumed to hold between these payoffs:

The flow of consumer surplus under each of these market structures is as follows:

- *s*: consumer surplus if no investment takes place;
- S^m : consumer surplus if a firm has exclusive access to infrastructure (regardless of who that firm is);
- $S^c(a)$: consumer surplus if both firms have access to infrastructure the seeker pays a unit price equal to *a*.

where it is assumed that,

[3] That is, there are the profits a provider would earn if access to its infrastructure was neither mandated nor regulated.

$$S^c(a) > S^m \geq s \text{ and } S^c(a) + \Pi_1^c(a) + \Pi_2^c(a) > S^m + \max\{\Pi_1^m, \Pi_2^m\} \geq s + \pi_1 + \pi_2 \geq 0 .$$

Therefore, the infrastructure is socially valuable and achieves its optimum under a duopoly rather than monopoly.

Socially optimal timing

The social planner solves the following problem:

$$\max_{T,a} \int_0^T (s + \pi_1 + \pi_2)e^{-rt}dt + \int_T^\infty (S^c(a) + \Pi_1^c(a) + \Pi_2^c(a))e^{-rt}dt - F(T) \text{ or} \tag{1}$$

$$\max_{T,a} \tfrac{1}{r}(s + \pi_1 + \pi_2)(1 - e^{-rT}) + \tfrac{1}{r}(S^c(a) + \Pi_1^c(a) + \Pi_2^c(a))e^{-rT} - F(T) \tag{2}$$

The solution to this, (T^{SO}, a^{SO}), satisfies the first order conditions:

$$S^c - s + 2(\Pi_1^c + \Pi_2^c - \pi_1 - \pi_2) = -F'(T^{SO})e^{rT^{SO}} \tag{3}$$

$$\frac{\partial(S^c(a^{SO}) + \Pi_1^c(a^{SO}) + \Pi_2^c(a^{SO}))}{\partial a} = 0 \tag{4}$$

Note that, given that marginal costs of infrastructure access are zero, it may be the case that $a^{SO} < 0$. It is assumed that $S^c(a^{SO}) - s + 2(\Pi_1^c(a^{SO}) + \Pi_2^c(a^{SO}) - \pi_1 - \pi_2) > rF$ so that T^{SO} is finite.

3. No Access Regulation

As a benchmark to evaluate the benefits of access regulation, it is useful to begin by considering the equilibrium outcomes in the absence of such regulation. As will be demonstrated below, no access regulation does not imply a lack of access. Nonetheless, there are several dimensions in which an unregulated outcome fails to achieve the social optimum.

Motives for access

Working backwards, it is useful to consider first the motivations of an unregulated infrastructure provider to provide access. Suppose that firm *i* invests and that *j* would like access. In the absence of a regulatory mandate, access will only be granted if there is a gain from trade to so doing. Note that this gain will be motivated by two concerns: a desire to preserve monopoly profits and a desire to avoid duplication of infrastructure investment costs.

It is assumed that parties negotiate over a two part tariff with fixed payment, p_i, and unit price of a_i. First note that in any agreement the parties will choose a_i to maximise: $\Pi_i^c(a_i)+\Pi_j^c(a_i)$. Denote this as $\hat{a}_i$ and observe that it will typically be above 0. This will not be the case if 1 and 2 operate in distinct markets (or sell into a perfectly competitive market; e.g., for export). In this case, $\hat{a}_i=0$. In such situations and environments where firms do not compete too intensely, it is entirely possible that $\Pi_i^c(\hat{a}_i)+\Pi_j^c(\hat{a}_i)\geq\Pi_i^m$.

Second, note that if $\Pi_i^c(\hat{a}_i)+\Pi_j^c(\hat{a}_i)<\Pi_i^m$, it will be profit maximising for *i* to deny *j* access. In this case, $p_i=0$. However, the possibility that *j* might duplicate the asset will constrain this outcome. Duplication gives the potential seeker a payoff of $\frac{1}{r}\Pi_j^c(0)e^{-rT}-F(T)$ if it invests at *T*. Let $\widehat{T}$ be the choice of *T* that maximises this function; and suppose that, as will generally be the case, this is later than the date at which a stand-alone monopolist would invest. This possibility imposes an upper bound on the access charge that the seeker will accept. That is, it must be the case that $p_i \leq \Pi_j^c(\hat{a}_i)$, but if $\Pi_j^c(0) \geq rF$ this upper bound is strengthened so that, if the infrastructure investment occurs at $\hat{T}$, $(\Pi_j^c(\hat{a}_i) - p)e^{-r\hat{T}} \geq \Pi_j^c(0)e^{-r\hat{T}} - rF(\hat{T})$.

Motives for investment

Turning now to the private incentives to investment, it is possible to distinguish between two different drivers of investment timing: *willingness to pay* and *pre-emption*.

Willingness to pay is a consideration of the direct private benefit from investment in the absence of any strategic concern. For firm *i*, if investment takes place at time T_i and they expect to receive an access price of p_i at time T_j, the present value of their payoff is:

$$\begin{aligned} W_i(T_i) &= \int_0^{T_i} \pi_i e^{-rt} dt + \int_{T_i}^{T_j} \Pi_i^m e^{-rt} dt + \int_{T_j}^{\infty} (\Pi_i^c(a_i) + p_i) e^{-rt} dt - F(T_i) \\ &= \tfrac{1}{r}\pi_i(1 - e^{-rT_i}) + \tfrac{1}{r}\Pi_i^m(e^{-rT_i} - e^{-rT_j}) + \tfrac{1}{r}(\Pi_i^c(a_i) + p_i)e^{-rT_j} - F(T_i) \end{aligned} \tag{5}$$

Let $\hat{T}_i$ be the value of T_i that maximises this function, taking into account the fact that T_j might be contingent in T_i. The first order condition for this maximisation problem is (assuming that a_i is independent of (T_i, T_j)):

$$\left(\Pi_i^m - \pi_i\right)e^{-r\hat{T}_i} + \tfrac{dT_j(\hat{T}_i)}{dT_i}(\Pi_i^c(a_i) + p_i - \Pi_i^m)e^{-rT_j} - \tfrac{1}{r}\tfrac{dp_i(\hat{T}_i)}{dT_i}e^{-rT_i} = -F'(\hat{T}_i) \tag{6}$$

Indeed, if $T_j = T_i$, as it may in equilibrium, then $\Pi_i^c(a_i) + p_i - \pi_i$ is *i*'s willingness to pay for the infrastructure.

The second motive driving infrastructure is strategic. There is a potential value to being the first firm to invest and *pre-empting* the other. By investing first at time T_i, *i* receives $W_i(T_i)$ above. However, if firm *j* invests first, firm *i* may have to pay *j* for access. It turns out that this is always preferred by *i* to duplicating the facility. Moreover, it is also the case that once the infrastructure is built, there is no benefit to *i* from delaying its access demand. Hence, if it expects an access price of (p_j, a_j), firm *i*'s payoff in the event that it does not invest first is:

$$L(T_i) = \tfrac{1}{r}\left(\Pi_i^c(a_j) - p_j\right)e^{-rT_i} \qquad (7)$$

where T_i is now the time that access is sought. If both firms choose to invest at the same time, then it is assumed that the provider is decided randomly so that firm *i* earns $\tfrac{1}{2}\left(W_i(T) + L_i(T)\right)$. Following Katz and Shapiro (1987), "firm *i* is willing to preempt at *T*" if $W_i(T) \geq L_i(T)$. Moreover, the assumptions on *F*(.) guarantee that the current pre-emption value, $\left(W_i(T) - L_i(T)\right)e^{rT}$, is increasing in *T*; that is, if it is worth pre-empting at some time, it is worth pre-empting at any time after that. With this in mind, the earliest pre-emption date for firm *i*, $\tilde{T}_i$, is defined by $W_i(\tilde{T}_i) = L_i(\tilde{T}_i)$ or, alternatively, $p_i + p_j = rF(\tilde{T}_i)e^{r\tilde{T}_i}$. Thus, $p_i + p_j$ is firm *i*'s *pre-emption motive* for investment. That is, the motive for pre-emption is the difference between being paid an access charge and having to pay an access charge. However, this implies that the pre-emption incentives are identical for both firms, i.e., $\tilde{T}_i = \tilde{T}_j$.

Negotiations over access

To consider fully what happens in the absence of access regulation, I work backwards: that is, asking first, what will be the outcome of access negotiations? To make things simple, I will label the provider as *P* and the seeker as *S* and assume that *P* has invested at T_P and that access is being sought at time $T_S \geq T_P$.

When *P* invests, it has the option of refusing access to *S*. As noted earlier, this will not occur if $\Pi_P^c(\hat{a}) + \Pi_S^c(\hat{a}) \geq \Pi_P^m$; where $\hat{a}$ is the level of the unit access charge that maximises joint profits. However, even if $\Pi_P^c(\hat{a}) + \Pi_S^c(\hat{a}) < \Pi_P^m$, *P* and *S* may come to an access agreement that involves $a_i = \infty$ and allows *P* to earn Π_P^m to prevent duplication of the infrastructure. This will occur whenever $\Pi_S^c(0) \geq F$. In this case, if it chose to by-pass *P*, *S* would earn: $v_S^{SA} = \max_T \frac{1}{r} \Pi_S^c(0) e^{-rT} - F(T)$.

Given this, if $\Pi_S^c(0) \geq rF$, *P* and *S* will begin negotiations at T_S over the access charges (*p*, *a*). This negotiation takes a non-cooperative form similar to Rubinstein (1982). That is, negotiations can place over time where in each period, one party is chosen at random to be the offeror and they make a take-it-or-leave-it offer to the offeree. That party either accepts the offer (in which case the game ends) or rejects it (in which case agreement is delayed, *P* continues to earn profits and the process is repeated in the next period). It is assumed that *S* can only opt out of the bargaining process when responding to an offer by *P*.[4]

This results in the following outcome:

Proposition 1. *Suppose that* $\Pi_S^c(0) \geq rF$. *The above bargaining game in continuous time has a unique subgame perfect equilibrium in which the initial offeror (whether S or P) makes an offer at* T_S *that is accepted immediately of:*

- $\tilde{p}(T_S) = \min\left[\frac{1}{2}\left(\Pi_S^c(\hat{a}) - \Pi_P^c(\hat{a}) + \Pi_P^m\right), \Pi_S^c(\hat{a}) - rv_S^{SA} e^{rT_S}\right]$ *and* $\tilde{a} = \hat{a}$ *if* $\Pi_P^c(\hat{a}) + \Pi_S^c(\hat{a}) \geq \Pi_P^m$;
- $\tilde{p}(T_S) = -rv_S^{SA} e^{rT_S}$ *and* $\tilde{a} = \infty$ *if* $\Pi_P^c(\hat{a}) + \Pi_S^c(\hat{a}) < \Pi_P^m$.

[4] This assumption is made in order to eliminate supergame effects (i.e., brinkmanship) and simplify the bargaining equilibrium (see Gans and Williams, 1999).

This proposition is an extension of Proposition 1 of Gans and Williams (1999). Note that in any case, S chooses to set $T_S = T_P$. That is, it seeks access as soon as the investment is built. This is because the equilibrium access charge is either independent or decreasing in the time that access is sought, so S would rather earn value sooner rather than later.

Equilibrium investment timing

In choosing when to invest, a firm will have regard to any expected access payments, as derived in Proposition 1. It is perhaps easiest to focus first on the case where an access seeker is "small" in the sense that it would never build the infrastructure. In this case, it is clear that $v_S^{SA} = 0$ and $\tilde{p}(T_S) = \frac{1}{2}\left(\Pi_S^c(\hat{a}) - \Pi_P^c(\hat{a}) + \Pi_P^m\right)$ if $\Pi_P^c(\hat{a}) + \Pi_S^c(\hat{a}) \geq \Pi_P^m$ and $\tilde{p}(T_S) = 0$ otherwise. Nonetheless, if it chooses to seek access, S does so as soon as the infrastructure is built, i.e., $T_S^N = T_P$. Anticipating this, P adjusts its timing accordingly. Therefore, P chooses T_P according to:

$$T_P^N = \arg\max_{T_P} \tfrac{1}{r}\max[\tfrac{1}{2}\left(\Pi_S^c(\hat{a}) + \Pi_P^c(\hat{a}) + \Pi_P^m\right), \Pi_P^m]e^{-rT_P} - F(T_P) \quad (8)$$

The profit maximising choice of T_P satisfies: $\max[\tfrac{1}{2}\left(\Pi_S^c(\hat{a}) + \Pi_P^c(\hat{a}) + \Pi_P^m\right), \Pi_P^m] = -F'(T_P^N)e^{rT_P^N}$. Notice that $\hat{T}_P^N \leq T_P^{SA}$, P's stand-alone investment timing where $T_P^{SA} = \arg\max_{T_P} \tfrac{1}{r}\Pi_P^m e^{-rT_P} - F(T_P)$.

What happens when both firms can potentially become infrastructure providers? In this situation, both pre-emption and willingness to pay motivations will play a role. Let T_i^N be i's investment timing choice if it were the only provider (as in (8)) and $v_{S,i}^{SA}$ the profits *i* would make if it by-passed *j*'s facility as a seeker. The following proposition characterises the equilibrium investment timing.

Proposition 2. *Suppose that* $T_i^N \leq T_j^N$ *, then (i) if* $\tilde{T}_i \leq T_j^N$ *there exists a unique equilibrium outcome with investment taking place at the earlier of* T_i^N *and* $\tilde{T}_i$*; (ii) if* $\tilde{T}_i > T_j^N$ *and* $W_i(T_i^N) \leq L_i(T_j^N)$ *there exists another equilibrium with investment taking place by firm j at* T_j^N.

This proposition is a special case of Theorem 1 of Katz and Shapiro (1987, p.410). Pre-emption incentives determine the equilibrium if the timing choice that equates the winning and losing payoffs for each firm is earlier than either firm's willingness to pay timing choice.

It is useful to note that equilibrium timing may be delayed, the same or accelerated relative to whether both firms were coordinating their investment timing decisions. A coordinated decision would implement timing on the basis of $\max\left[\max_i\left[\Pi_i^c(\hat{a}_i)+\Pi_j^c(\hat{a}_i)\right], \max_i \Pi_i^m\right]$. Suppose that for both firms $v_{S,i}^{SA}$ was sufficiently high so that the access charges were constrained to prevent the seeker from by-passing the facility. In this case, the willingness to pay timing of the preferred provider would be the same as that which would arise from a coordinated decision. However, here, equilibrium timing could be earlier than this date if the motive for pre-emption is strong and it could be later than this date if the motive for pre-emption is very weak.

Summary

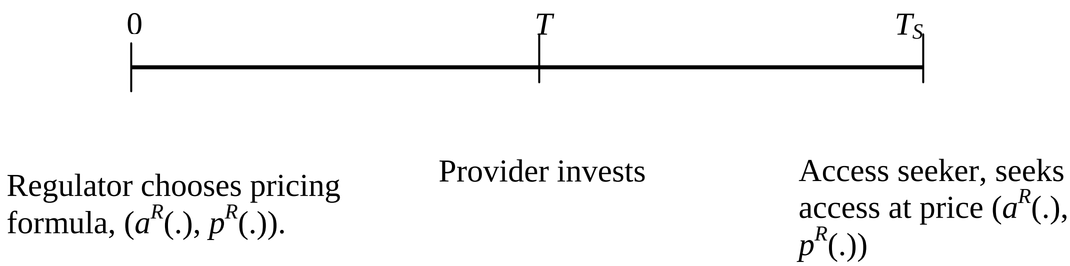
There are several social costs arising in the no regulation case. First, when one firm is "small" investment timing will be delayed relative to the social optimum. The provider will not appropriate sufficient firm rents – let alone consumer surplus – to make the socially optimal decision. In any case, access does not equate with the achievement of maximum social surplus (which would require access and $a = a^{SO}$). Second, when both firms are "large" competition amongst them potentially accelerates investment timing. It is entirely possible that in this situation, infrastructure investment could be provided too soon at too high an investment cost or with an inefficient technology.

4. Access Price Regulation

Given that in the absence of access regulation investment timing is not socially optimal and downstream competition will not be as intense as it may be, it is worthwhile to consider regulated access prices that could improve outcomes. In this section, it is assumed that the timing of the model is as in Figure One. The regulator chooses a two part tariff pricing formula, both parts of which may depend on the time the infrastructure is built and the time access is sought. Knowing this the provider chooses their investment time and the seeker chooses a time to seek access. As in previous sections, it is useful to distinguish between the "small" and "large" seeker cases.

In this section, the focus is on the setting of the fixed charge. As such we suppose that $a^R = 0$ as this simplifies notation. Specifically, given then upstream marginal costs are assumed to be zero, it means that the flow of profits (net of access revenue or payments) for any firm is the same regardless of whether it is an access seeker or access provider.[5] In the next section, this condition is relaxed. Given this, through this section, for notational convenience, I set $\Pi_i^c \equiv \Pi_i^c(0)$ and $S^c \equiv S^c(0)$.

Figure One: Model Timeline



"Small" Seekers

Suppose that only one firm is large, in the sense of being able to provide the infrastructure. The no regulation choice of investment timing is delayed relative to the socially optimal timing because *P* does not appropriate the full social returns from its decision. Of course, setting $p^R = S^c(a^{SO}) + \Pi_S^c(a^{SO})$ and $a^R = a^{SO}$ would implement the social optimum. However, this would require both a subsidy and merging both firms. This does not appear to be a practical outcome.

Suppose instead that, similar to the reality of the practice of access pricing, we considered solutions based on cost-sharing rather than a reallocation of benefits. Suppose that the regulated access price is of the class $p^R = \alpha F(T_S)e^{rT_S}$; that is, a share of the

[5] This is, in fact, the usage charge that would lead to a competitively neutral outcome. See Gans and King (2004b).

replacement cost of the infrastructure valued at the time access is sought.[6] Notice that in this case, α needs to be chosen to satisfy two desires. First, that access is sought immediately and, second, the provider has appropriate incentives.

Note that, for a given α, the preferred timing for P and S are given by the following first order conditions:

$$\frac{\Pi_P^c}{1-\alpha} = -F'(T)e^{rT} \text{ and } \frac{\Pi_S^c}{\alpha} = -F'(T)e^{rT} \tag{9}$$

These are in agreement if and only if,

$$\frac{\Pi_P^c}{1-\alpha} = \frac{\Pi_S^c}{\alpha} \Rightarrow \alpha = \frac{\Pi_S^c}{\Pi_P^c + \Pi_S^c} \tag{10}$$

Therefore, each firm pays a proportion of the assessed costs equal to its share of total profits. If these use-values are observable to the regulator ex post they can be used as part of the regulated access price. Let T^C be the coordinated investment timing decision that satisfies:

$$\Pi_P^c + \Pi_S^c = -F'(T^C)e^{rT^C} \tag{11}$$

It is easy to confirm that $\hat{T}_P^R = T^C$ and that $\hat{T}_S^R = \hat{T}_P^R$ so that the coordinated investment timing is in fact implemented for this cost sharing regime.[7]

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[6] Gans and Williams (1999) and Gans (2001) compare methodologies based on replacement cost and historic cost. Both are equivalent if access is sought immediately but if there is some delay, they demonstrate that replacement cost creates superior investment timing incentives.

[7] It turns out that in this framework, the regulator's problem is equivalent to finding the Lindahl equilibrium in this setting. The choice of investment timing is in fact a choice regarding the level of a public good. A Lindahl equilibrium occurs when for a given cost sharing arrangement, both firms prefer the same level of the public good; in this case, investment timing. See Gans and Williams (1999) for an extensive discussion.

Two "Large" Firms

If both firms can be potential providers, then the regulated access price plays a critical role in driving competition for provision. The basic idea is that even if $a_i^R < \hat{a}_i$ then competition to receive and avoiding paying fixed access charges drives investment timing. Indeed, for an appropriately specified formula, $p_i^R(.)$, it is possible that investment timing could be socially optimal despite the fact that competition is prevailing.

The key to this is to recall that for a given set of expected access charges, $p_1(.)$ and $p_2(.)$, for all *i*, pre-emption timing is determined by: $p_1 + p_2 = rF(\tilde{T}_i)e^{r\tilde{T}_i}$, so that $\tilde{T}_1 = \tilde{T}_2 = \tilde{T}$. On the other hand, if access is sought immediately, willingness to pay timing is determined by $\hat{T}_i \equiv \arg\max_{T_i} \frac{1}{r}\pi_i(1-e^{-rT_i}) + \frac{1}{r}(\Pi_i^c + p_i(T_i))e^{-rT_i} - F(T_i)$. Given this, the subgame perfect equilibria in the investment timing game are summarised in the following proposition.

Proposition 3. *Suppose that* $p_1(.)$ *and* $p_2(.)$ *are such that access is always sought immediately. Suppose, also, that* $\hat{T}_1 < \hat{T}_2$. *Then, equilibrium timing is* $\hat{T}_P = \min[\hat{T}_1, \tilde{T}]$. *If* $\hat{T}_1 < \hat{T}_2 < \tilde{T}$, *there is a second equilibrium in which 2 invests at* $\hat{T}_2$ *if and only if* $W_1(\hat{T}_1) \leq L_1(\hat{T}_2)$.

Note that it is possible that either firm could be the provider. Indeed, even where it would never be profitable for a firm to invest as a stand-alone entity, i.e., $\Pi_i^m < F$, it could be profitable for them to invest as a provider of access so long as $\Pi_1^c + \Pi_2^c > rF$.

Investment timing is uniquely determined by the choice of regulatory pricing formula, $p_i^R(.)$. The regulatory issue then becomes whether $p_i^R(.)$ can be chosen so that

$T_P^R = T^{SO}$ and $T_S^R = T_P^R$? The latter condition will be satisfied so long as the value of seeking access at T_P^R is decreasing in T_S.

The following proposition derives a pricing formula that implements the socially optimal investment timing and access seeking choices.

Proposition 4. *Assume that* $\Pi_1^c + \Pi_2^c - rF(T^{SO})e^{rT^{SO}} \geq r\max\left[v_1^{SA} + v_2^{SA}, 0\right]$. *Then there exists some weights,* α_i *(with* $\alpha_1 + \alpha_2 = 1$*) so that the following regulated prices:*

$$p_i^R(T_S) = \alpha_i\left(S^c - s + \Pi_1^c - \pi_1 + \Pi_2^c - \pi_2\right) + \alpha_i\left(r + \tfrac{F'(T_S)}{F(T_S)}\right)F(T_S)e^{rT_S}$$

results in $T_P^R = T^{SO}$ *and* $T_S^R = T_P^R$.

This proposition is proved by Gans (2001). The condition in this proposition has an intuitive interpretation. It simply allows private investment and competition to be feasible. That is, industry profits when investment takes place at the socially optimal date are positive and exceed profits if each were to duplicate the facility.

The above formula achieves a socially optimal result by doing two things. First, $p_i^R(T_S)$ as stated in the proposition may be decreasing in T_S. However, because of the convexity of current costs in *T*, the seeker prefers to receive its payoff, $\Pi_j^c - p_i^R(T_S)$, sooner rather than waiting for a lower access price. Thus, access is sought immediately regardless of when the infrastructure is built. This also means that a seeker's payoff is falling the late the infrastructure is provided.

Given this, each firm expects that there will be no period of earning monopoly profits following the building of the infrastructure. Given this, the pricing formula controls investment timing by manipulating each firm's pre-emption incentives. If infrastructure is provided too late, as $p_i^R(T_S)$ is decreasing, this will reduce the access revenue a provider receives. Thus, a provider's payoff is increasing in T_P. Note, however, that this means that the relative payoff to being a provider over a seeker is rising over time. What this means is that any individual firm cannot afford to wait to become the provider lest they be pre-empted to any rents from this. Competition for those rents causes investment timing to be driven solely by pre-emption concerns.

From this it is easy to see how the regulated pricing formula is derived. Recall that pre-emption timing implies that: $p_1^R(\tilde{T}) + p_2^R(\tilde{T}) = rF(\tilde{T})e^{r\tilde{T}}$. The formula itself is one for which $\tilde{T} = T^{SO}$. Recall that T^{SO} is determined by the condition:

$$S^c - s + 2(\Pi_1^c + \Pi_2^c - \pi_1 - \pi_2) = -F'(T^{SO})e^{rT^{SO}} \tag{12}$$

Therefore, the pricing formula is such that:

$$S^c - s + 2(\Pi_1^c + \Pi_2^c - \pi_1 - \pi_2) + F'(\tilde{T})e^{r\tilde{T}} = p_1^R(\tilde{T}) + p_2^R(\tilde{T}) - rF(\tilde{T})e^{r\tilde{T}} \tag{13}$$

$$p_1(\tilde{T}) + p_2(\tilde{T}) = \underbrace{S^c - s + \Pi_1^c - \pi_1 + \Pi_2^c - \pi_2 + F'(\tilde{T})e^{r\tilde{T}}}_{\text{Marginal Social Cost of Delay}} + \underbrace{rF(\tilde{T})e^{r\tilde{T}}}_{\text{Investment Cost Recovery}} \tag{14}$$

Note that, in equilibrium, the first term is zero by definition. As such, the regulated pricing outcome involves a fixed access charge that has each firm share the costs of infrastructure provision.

(14) gives the regulator considerable choice as to the formula determining the actual price that will be charged to a given firm. What criteria should be used to select among alternative weights in Proposition 4? It is easy to see that if fixed charges exceed a seeker's on-going profits, then the seeker will not participate in the regime. For both $\Pi_1^c \geq p_2^R$ and $\Pi_2^c \geq p_1^R$ to be satisfied,

$$\alpha_1 = \frac{\Pi_1^c}{\Pi_1^c + \Pi_2^c} \text{ and } \alpha_2 = \frac{\Pi_2^c}{\Pi_1^c + \Pi_2^c} \tag{15}$$

As in the "small" seeker case, each firm pays a share in proportion to the profits they make in duopoly. In equilibrium, each firm ends up sharing in investments costs according to the same weights, α_i.

This method of cost allocation is similar to a fully distributed cost methodology and, in equilibrium, it is indistinguishable from it. However, the rationale behind the allocation is solely to encourage competition in infrastructure provision. That is, the shares are set so as to make it possible for both firms to be able to pay their respective charges whenever private investment is feasible, i.e., $\Pi_1^c + \Pi_2^c \geq rF(T^{SO})e^{rT^{SO}}$ implies $\Pi_i^c \geq p_j^R$ for all i, j.

Summary

Proposition 4 demonstrates that it is possible for a regulator to use fixed access charges to induce socially optimal investment timing even when there is immediate competition. It does this by manipulating the pre-emption incentives of potential providers. If there were no such strategic motive, then it would be impossible to use an investment race to achieve timing earlier than the date that would arise for an unregulated monopolist. Indeed, the regulation potentially prevents wasteful acceleration of infrastructure investment provision.

5. Practical Issues

There are some practical issues that are worth considering when analysing the regulation of access and its impact on investment. These include how usage charges should be determined, whether access negotiations should be mandated and whether access holidays may be used. Each of these is discussed in turn.

Optimal usage charges

Above, the usage component, a^R, of the regulated access pricing regime was taken as given. Nonetheless, all of the previous literature on access pricing has been concerned with the level of such charges. In particular, for the complete information environment of this paper, it has been argued that the optimal usage charge should be set below upstream marginal cost to counter the effects of imperfect competition downstream (Armstrong, Doyle and Vickers, 1996).

This issue is relevant here in so far as feasibility requirement is concerned – that it is privately profitable to invest at the socially optimal time rather than delay or duplicate the facility or not invest at all. If downstream profits are insufficient for this requirement to be met, then a usage charge below marginal cost designed to lower final good prices may be undesirable. It may be better to lift the usage charge and allow some downstream profits, so that the industry as a whole breaks even.

To see this, suppose that both providers are symmetric.[8] It is readily apparent that a^R should be as close to a^{SO} as possible. In particular, the lower bound is defined by: $\Pi_1^c(a^R)+\Pi_2^c(a^R)-rF(T^{SO})e^{rT^{SO}}=r\max\left[v_1^{SA}+v_2^{SA},0\right]$. For a given a^R, the earliest pre-emption date, $\tilde{T}$, is now defined by:

[8] This is not an innocuous assumption. If they were different, then their regulated and usage charges would be different as they would face different marginal costs as a vertically integrated provider. This, in turn, would mean that fixed charges alone would not determine investment timing and the pre-emption incentives for each firm would be different. As such, this would become a considerably more complex problem and beyond the scope of this paper to resolve quantitatively. Nonetheless, many of the qualitative issues would continue in this case.

$$\Pi_P^c(a^R) - \Pi_S^c(a^R) + 2p^R = rF(\tilde{T})e^{r\tilde{T}} \qquad (16)$$

This means that the socially optimal fixed charge should equal:

$$p^R(T_S) = \tfrac{1}{2}\left(S^c - s + 2\left(\Pi_S^c(a^R) - \pi\right)\right) + \left(r + \tfrac{F'(T_S)}{F(T_S)}\right)F(T_S)e^{rT_S} \qquad (17)$$

In equilibrium, fixed charges amount to a sharing of investment costs. In contrast, the usage charges are set to ensure participation. From an industry-wide perspective, this represents an implementation of Ramsey or average cost pricing downstream; where average costs include the sunk costs of investment upstream. Nonetheless, this highlights the fact that because usage charges affect the distribution of industry rents as well as their overall size, it must be taken into account when setting regulated fixed charges.

Access Holidays

The difficult feature of the above models of access pricing is that they require regulatory commitment of the pricing formula prior to any investment taking place. The complete information problem here masks the considerable uncertainty that surrounds most investment. In this situation, regulators may be unable to commit to a specific formula or even an appropriate methodology in advance that respects uncertainty that may occur. This is a problem because it may be the case that access is only sought when the investment is "successful" and not otherwise. Given this, Gans and King (2004a) demonstrate that a 'truncation problem' may arise whereby investors are penalised when their investment is successful and not sufficiently rewarded for risk borne.

A potential solution to this is to give access providers a period of time following investment that is free of required access regulation; that is, an "access holiday," Of course, as noted earlier, a provider may choose to grant access anyway. However, the point is that access, if any, will not be subject to a regulatory constraint. In this respect, an access holiday is similar to a patent. The difference, however, is that when access regulation occurs, that regulation can be optimal. Gans and King (2004a) consider a situation where that access regulation is such that social surplus is maximised and the provider's investment returns from that point on are normal. That is, the provider is regulated in a fashion that just allows them to recover depreciated investment costs.

While Gans and King (2004a) model uncertainty explicitly, here I consider a version of their model where the investment outcomes are always certain. Suppose that an investment takes place at time, T_P, and that both firms are symmetric. In addition, suppose that during the holiday period the provider does not grant access. The provider is granted a holiday period of τ and so is only subject to access regulation at time $T_P + \tau$. That regulation is assumed to be optimal and, as such, (p^R, a^R) is set so that:

$$\int_{\tau}^{\infty}\left(\Pi_P^c(a^R)+p^R\right)e^{-rt}dt=\tfrac{1}{r}\left(\Pi_P^c(a^R)+p^R\right)e^{-r\tau}=F(T_P)e^{r(T_P-\tau)} \qquad (18)$$

Thus, a provider is able to earn monopoly profits for τ periods but must also bear the flow of capital costs, $F(T_P)e^{rT_P}(1-e^{-r\tau})$, over that period. Thus, the provider's willingness to pay incentive is determined by:

$$W(T_P)=\tfrac{1}{r}\Pi_P^m e^{-rT_P}(1-e^{-r\tau})-F(T)(1-e^{-r\tau}) \qquad (19)$$

It is natural to suppose that, given the symmetry between firms, an access seeker will not make positive profits upon the holiday's expiry. In this case, $L(T_S)=0$. Of course, this means that the seeker is indifferent between seeking access and not. To avoid complications, I assume that it seeks access immediately.

What this means is that, if one firm happened to be unable to provide the infrastructure, then timing would be determined according the timing that maximises (19) . It is very easy to see here that the infrastructure is provided at the time an unregulated monopolist would choose to invest. Critically, it is independent of the length of the access holiday, τ. This means that, in theory, the regulator could set the holiday period arbitrarily small without deterring investment timing.[9] However, as Gans and King (2004a) show this is not robust to realistic changes to the model, such as to allow demand changes over time, that make profit flows depend upon time, *t*. Instead they demonstrate that if profits are front loaded over time (relative to the access holiday length and the rate of technological progress on investment costs), then investment may occur earlier than the monopoly timing.

On the other hand, if both firms can potentially provide the infrastructure, for a given access holiday, firms will compete away the rents associated with $\max_{T_P} W(T_P)$ and the investment will occur earlier than it would under an unregulated monopoly. However, the investment acceleration itself will depend upon the length of the holiday. Nonetheless, in principle, so long as private rents in the industry are sufficient to cover investment costs, there exists an access holiday that implements the socially optimal (or at least second best) investment timing. Thus, access holidays play a similar role to fixed access charges although they mean that there is a delay to the advent of downstream competition.[10]

[9] This result appears related to Sappington and Sibley (1988).
[10] Given a choice it is better to use access pricing than an access holiday. When social welfare is concave, then it is better to spread any deadweight losses over time than put them all earlier in a concentrated manner (see Gilbert and Shapiro, 1990).

6. Conclusion

To date, the research into the impact of access regulation on investment incentives has considered some fairly specialised models in order to (i) demonstrate that such regulation can improve investment outcomes; (ii) demonstrate that there need not be a trade-off between encouraging competition and encouraging investment; and (ii) suggest that existing approaches of allocating sunk investment costs based on a fully-distributed cost methodology may have, at least to a point, some grounding in economic theory.

That said, we are still far from a set of pricing rules that can be reliably used in practical situations. Nonetheless, what the models to date show is that there is a methodology and approach regulators could use to consider this and that putting in place clear guidelines and commitments is surely desirable. Infrastructure investments are substantial and involve considerable risk. Adding regulatory risk is certainly a recipe for poor outcomes. Only by providing clear commitments can regulatory access rules improve upon private arrangements.

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